Economic impact of the John Innes Centre

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Executive summary

The John Innes Centre (JIC) is a not-for-profit organisation sponsored by the Biotechnology and Biological Sciences Research Council (BBSRC).

JIC commissioned DTZ to undertake a statement of its economic impact in 2008. This report contains estimates of economic impact relating to the activities of JIC. However, given the scale and breadth of JIC's work, it does not represent a comprehensive assessment, rather a snapshot.

JIC addresses a range of market failures that provide the rationale for its support from Government. These failures are summarised in the following table.

Summary of market failures addressed by JIC		
JIC key activity	**Funding justification (Key market failure)**	**Nature of failure**
Quantitative research (volume of produce e.g. higher yield, adaptive to climate change)	Public good	Fundamental research may be time consuming and uncertain in its outcomes, thus the private sector may not invest, reducing the availability of improved quality, safe food products.
Qualitative research (improved traits of produce e.g. enhanced nutrients)	Externalities	Social outcomes (the benefits from improved health or environmental conditions) are greater than the private return companies can generate from sale of improved products.
Outreach and engagement with the public	Information failure	Consumers may lack the skill to understand the risks of certain purchases, and lack the capacity to gather this information individually and independently. This JIC role therefore promotes social benefits by reducing risk.

The activities of JIC have a financial impact and provide benefits to the economy via its operating impact, final market impacts and wider qualitative benefits.

Operating Impacts

Summary of JIC operating impacts, UK level				
Impact type	**Output £ Million**	**Employment FTEs**	**Income £ Million**	**GVA £ Million**
Direct	£27.5	378	£16.3	£16.3
Indirect	£32.1	289	£7.6	£13.7
Induced	£23.8	283	£6.2	£12.3
Total	**£83.4**	**950**	**£30.1**	**£42.4**

Final Market Impacts

The calculation of final impacts for JIC is set out below under four headings:

Cereal Crops

- Wheat: through the development of the semi-dwarfing gene, JIC has helped to increase UK wheat production by £75 million per annum. Its contribution to world wheat production is estimated at £3.4 billion.
- Cereal diseases: JIC's work with genetically resistant cultivars and fungicide treatments supports global cereal production. JIC's work to mitigate major losses in world wheat production could potentially be as much as £4.3 billion per annum.
- Synteny: JIC's gene mapping is helping to address world hunger, and can be seen as leveraging World Bank funding of $5.2 million (£2.6 million) per annum into organisations such as IRRI (in the Philippines) and CIYMMT (in Mexico).

Other crops

- Through research into semi-leafless varieties, JIC's work underpins the £38 million annual UK pea market, with directly attributable sales of £2.9 million per annum.
- "Super-Broccoli" research is adding value to consumers in the UK of £0.5 million per annum, and may also contribute to reduced incidence of colon cancer.

Antibiotics

- JIC discovered the genetic basis of antibiotic properties by *Streptomyces*, a global market now worth $35 billion per annum.
- A JIC spin-out company (Novacta Biosystems) has recently received a £3 million Wellcome Trust grant to work on solutions to *Clostridium difficile* and MRSA. If successful, this work could add £194 million to the UK economy through prevention of avoidable deaths.
- A new spin-out company (Procarta Biosystems) is developing a completely new approach to overcome antibiotic resistance that could have broad application.

Cross Cutting Impacts

- JIC has developed intelligent breeding research, which can potentially reduce the breeding time for varieties with enhanced resistance characteristics by up to 15 years.
- Income from commercial sources to JIC is estimated to generate an additional £5.2 million GVA in the economy per annum.
- JIC receives £171k per year of royalty income.

1.0 Introduction

RCUK wishes all research councils to have institutes prepare statements of their economic impact by end of March 2008. These statements will be used to inform the UK government spend on science and technology and to illustrate where best value for money is being achieved.

The John Innes Centre (JIC) is a not-for-profit organisation sponsored by the Biotechnology and Biological Sciences Research Council (BBSRC).

The BBSRC's delivery plan 2008 – 2011: "Delivering Excellence with Impact", set in the context of HM Treasury's Grand Challenges for Science, outlines the priority areas for the current funding period. These are summarised as:

1. Ensuring the continued health and international competitiveness of UK bioscience;

2. Driving a step-change in the economic and social impact of funding;

3. Providing the skilled people upon which the science base and bio-industries depend;

4. Tackling major policy and societal long-term and multidisciplinary challenges; and

5. Securing national research capability and unique facilities in key strategic areas.

To this end, it is increasingly important to understand the benefits and market impacts generated through each of the funded research institutes.

JIC commissioned DTZ to undertake the work necessary to produce a statement of its economic impact.

The activities of the JIC have a financial impact and provide benefits to the economy via a number of routes:

- **The operating impact**: this occurs as JIC's income contributes to national GDP, expenditure is incurred with suppliers, staff are employed and salaries earned. This impact is achieved regardless of the level of research success.

- **Final market impacts:** these occur as the outcomes of JIC's research are applied in the market, through use of products or implementation of strategic advice. This can capture new positive impacts (such as improved sales) and avoidance of negative impacts (such as crop wastage).

- The work of JIC generates a number of **wider social and environmental benefits** that are less tangible, and difficult to quantify in terms of additional turnover or jobs.

This report highlights and quantifies the range of economic impacts generated around the UK through the on-going research at the JIC. It also describes key achievements of the institute since its inception and identifies a range of non-quantifiable benefits attributable to JIC.

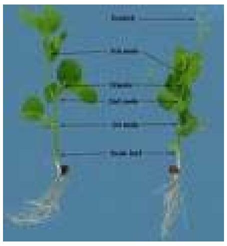
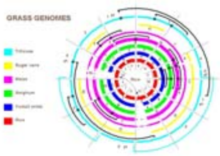
2.0 Background to the Institute

The John Innes Centre, as it is known today, was formed from:

- The John Innes Institute
- The Plant Breeding Institute (formerly at Cambridge)
- The Nitrogen Fixation Laboratory (formerly at Sussex)

The following timeline provides a summary of some of JIC's key achievements since its foundation:

YEAR	OVERVIEW OF ACHIEVEMENTS	
1905		The future founder of the John Innes Horticultural Institution, William Bateson, coins the phrase "genetics".
1910		John Innes Horticultural Institution founded at Merton, South London.
1916		The early work of the Plant Breeding Institute was devoted to the breeding of improved varieties of wheat. In 1916, the variety "Yeoman" was released, which set a standard for yield and grain quality that would last for many years. Over its 75 year history the PBI produced over 130 new varieties of wheat, barley, oats, triticale, potatoes, field beans, maize, oilseed rape, clover, sugarbeet and grasses.
Mid-1930s		In the mid 1930's the formulae for the 'John Innes Composts' were developed at the Institution to provide a sterile, well-balanced growing medium for experimental plant material. These formulae were subsequently released to the public.
Post-1945		A method for propagating roses was developed that is the basis of the technique still used to produce millions of roses annually.

1970s		The first registered 'semi-leafless' pea varieties arose out of research and breeding work at the JIC. The improved crop productivity and standing ability led to the use of 'semi-leafless' worldwide and they account for 100% of current UK dried pea varieties.
Mid to late 1970s		In the 1960s and 70s a 'Green Revolution' in world agricultural production took place during which world wheat yields almost doubled. This resulted from the introduction of dwarfed, high-yielding wheat varieties based on PBI's research and new cultivation methods.
1995		JIC's research on cereal genome structure revealed conservation in gene order (synteny) between all cereal species, enabling a step-change in breeding strategies and the cloning of genes from these species.
1999		Through its research on synteny in cereals, and model plant species, in this case Arabidopsis, JIC identified and isolated the dwarfing gene that was central to the green revolution.
2001		JIC pioneered the genome sequencing of. *Streptomyces.* These soil-inhabiting microbes are the source of most of the antibiotics used to treat infections, and they also provide us with a wide range of other drugs used in human and veterinary medicine including anti-cancer drugs and immunosuppressants. Genome analysis is used to increase antibiotic productivity and in the search for new antibiotics for the future.
2006		The characterisation of a gene that controls how chromosomes pair enables a step-change in approaches to introduce new characters into cereal crops.

While JIC can point to a number of past achievements, the fundamentals which have driven historic efforts in agricultural research have changed. These fundamentals were:

- Freely available inorganic fertiliser
- Increasing use of herbicides and pesticides (some of which are now much more tightly controlled)
- General intensification as a result of the drive for food security

There is a new paradigm which requires productivity to be maintained in the context of:

- Sustainability of oil supplies which are required for fuel and fertiliser production
- Resultant concern over energy supply and a potential increased role for plant biomass
- Climate change which may affect the sustainability of current varieties
- Growing population creating increased demand for food and potential land-use conflict.

These new long-term drivers create a requirement to adapt historic research and prepare for the future.

3.0 Why JIC receives funding

The HM-Treasury Green Book guidance states that there must be clear rationale for public sector interventions, and that:

"*This underlying rationale is usually founded either in market failure or where there are clear government distributional objectives that need to be met*"[1]

There is debate around the funding of research in the UK. For example, the Barnes Report,[2] classifies agricultural R&D into two categories, a near market category (undeserving of public funding) and fundamental research (which should receive public funding). On the other hand, a more recent 2004 DEFRA study[3] concludes that:

"the market failure concept continues to apply to the provision of near-market research in British Horticulture".

JIC is currently focused towards fundamental research, and its funding profile, based on the excellence of its research activities, accordingly points to predominantly public sources. Near market research is however also recognised through participation in the LINK programme, where the institute had 44 industrial collaboration partners in 2007, across the areas of sustainable arable production and food quality. JIC has also established an operational framework for the translation of its fundamental breakthroughs into economically important crops and microbe-based applications.

This section looks at the key areas of JIC research and the rationale for public sector funding in each case.

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[1] HM-Treasury, Green Book: Appraisal and Evaluation in Central Government, pp11

[2] *Report on a review of expenditure by the agricultural departments on research and dev*elopment C.J.A. Barnes for MAFF April 1988

[3] Report of the 2004 statutory review of the Horticultural Development Council, DEFRA July 2004

3.1 Research activities

JIC's core research areas can be broadly classified under the following headings:

Figure 3.1
Summary of JIC research activities

Research field	Workstreams	Research goals
Cereal Crops	▪ Wheat (semi-dwarfing genes) ▪ Cereals ▪ Barley ▪ Flowering time / heterosis ▪ Arabidopsis	▪ Improved yield traits ▪ Harvesting benefits ▪ Accelerated breeding ▪ New varieties ▪ Reduced wastage ▪ Responsive to climate change ▪ Increased geographical range of crop
Other crops	▪ Peas – semi-leafless ▪ Super broccoli ▪ Broccoli – longer season ▪ Brassica genetic mapping ▪ Arabidopsis	▪ Enhanced nutrient content ▪ Reduced wastage ▪ Easier harvest ▪ Reduced morbidity ▪ Reduced fertiliser use
Antibiotics	▪ Strain improvement ▪ Genome technologies ▪ Resistance technology	▪ Improved productivity ▪ New antibiotics entering clinical trials
Cross cutting	▪ Fundamental research ▪ Research Clusters o Plant diseases o Environmental stress o Flowering time	▪ Crop development ▪ Environmental benefits

3.2 Addressing market failure

Market failure is when the market, by itself, has not and cannot be expected to deliver an efficient outcome. Thus, any research intervention must seek to redress this failure in the market. Market failures can be qualitatively applied to each area of activity within JIC, indicating the requirement for research regardless of the financial value of impacts.

There are a number of factors to consider in setting out the market failure relevant to government intervention in food research (and BBSRC sponsorship of JIC) and these are discussed below under the following headings:

- Public goods
- Externality
- Information asymmetry

Public goods

"The market may have difficulty supplying and allocating certain types of products and services, such as 'public goods'. Public goods are those that are 'non-rival' or 'non-excludable' when used or consumed. 'Non-rival' means that consumption of the good by one person does not prevent someone else using or consuming that good. 'Non-excludable' means that if a public good is made available to one consumer, it is effectively made available to everyone. Non-excludability can give rise to a problem known as 'free-riding'."[4]

Public goods are those that provide social benefits that are large in comparison to their private benefits. Government intervention is necessary to achieve public good investment in horticulture research that may benefit all of industry through reduced disease, improved yield or improved understanding of productivity.

Horticultural research involves scientific expertise and equipment investment. There is little incentive for any individual company in the industry to bear the full investment, particularly when success is not guaranteed, unless they can secure exclusive use of any new innovations. This means that a large proportion of the industry would be excluded from advantageous innovation, resulting in reduced social benefits as the monopoly supplier seeks to make a financial return on its investment. To achieve the desirable social outcomes of improved health and nutrition, the government must therefore enhance access to any such beneficial research. This failure applies across all areas of fundamental research undertaken by JIC.

Externalities

"'Externalities' result when a particular activity produces benefits or costs for other activities that are not directly priced into the market. Externalities are associated with, for example, research and development spill-overs, and environmental impacts, such as pollution."[5]

In summary, the implied under-supply of plant research in the absence of government intervention is due to the fact that the companies' private benefits from actions taken to produce more health and environmental benefits are smaller than the benefits to society as a whole.

Furthermore, there are externalities related to research and development (R&D), particularly fundamental research where ideas are difficult to patent so the financial return on research is lower than the total social return. For example, the discovery by JIC of conserved genome structure in the cereal species (synteny) would be an excellent example of this, discussed in section 5. Therefore, public funding is provided to address the market failure. The Barker Report into Food Poverty (2006) notes this is the context of nutrition research:

"*whilst the poorest consumers may have needs that differ from the average consumer, the market should still serve those needs. Our work indicates that communities continue to experience market failure in the provision of nutritious food*"[6]

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[4] *The Green Book – Appraisal and Evaluation in Central Government* HM Treasury, Crown copyright
[5] *The Green Book – Appraisal and Evaluation in Central Government* HM Treasury, Crown copyright
[6] Food Poverty and the OFT's Consultation – referenced by HM-Treasury, available at: http://www.hm-treasury.gov.uk/media/A/A/barker2_interimResponse_FoodPoverty_85.5kb.pdf

More generally, the 2006 Stern report notes that:

"Climate change is the greatest and widest ranging market failure ever seen"

This failure is addressed through a number of JIC's research workstreams, in particular the crop and cross-cutting research focussed towards nutritional and environmental enhancement. These innovations lead to enhanced social benefits beyond the price that producers are able to realise for the products, and thus there would be underinvestment if left to the private sector.

Information Asymmetry

"Information is needed for a market to operate efficiently. Buyers need to know the quality of the good or service to judge the value of the benefit it can provide. Sellers, lenders and investors need to know the reliability of a buyer, borrower or entrepreneur. This information must be available fully to both sides of the market, and where it is not, market failure may result. This is known as 'asymmetry of information'."[7]

In addition to the issues described above relating to information asymmetry, which are related to the distribution of information, are issues concerning the overall level of information available in the market. In terms of the production of information, there are often high costs of production but low costs of subsequently transmitting information that may dampen incentives to produce information given the difficulties of controlling its usage by other parties (limited excludability). This can ultimately lead to low levels of available information. The subsidising or funding of R&D activities by Government is one way of addressing these market tendencies.[8]

JIC addresses this failure through highly cited peer-reviewed research publications, and its on-going outreach and engagement programmes with the public. This includes active promotion of science education programmes, and improves public awareness and understanding of core issues.

[7] *The Green Book – Appraisal and Evaluation in Central Government* HM Treasury, Crown copyright

[8] *Economics of regulation, charging and other policy instruments with particular reference to farming, food and the agri-environment – A supporting document for Partners for success – a farm regulation and charging strategy* Tim Keyworth and George Yarrow, Regulatory Policy Institute, Oxford for Defra, October 2005

Summary of failures addressed by JIC

Figure 3.2
Summary of market failures addressed by JIC

JIC key activity	Funding justification (Key market failure)	Nature of failure
Quantitative research (volume of produce e.g. higher yield, adaption to climate change)	Public good	Fundamental research may be time consuming and uncertain in its outcomes, thus the private sector may not invest, reducing the availability of improved quality, safe food products.
Qualitative research (improved traits of produce e.g. enhanced nutrients)	Externalities	Social outcomes (the benefits from improved health or environmental conditions) are greater than the private return companies can generate from sale of improved products.
Outreach and engagement with the stakeholders	Information failure	▪ Government poorly informed on impacts of use (risk), and potential, of technologies when developing policy ▪ Consumers poorly informed on the risks of technologies, impairing their participation in formation of policy or in making informed decisions about purchasing.

4.0 Operating impact of the JIC

4.1 Modelling approach

The economic impact of operating the JIC measures both the activity relating to the on-site running of the Institute, such as expenditure incurred and staff employed, and also the knock-on effects as these expenditures ripple through the UK economy and support further activities. The total economic impact of operating JIC therefore encompasses three distinct elements:

1. **Direct impact:** output generated and persons employed in the day-to-day operation of the Institute, on-site in Norwich:

2. **Indirect impact:** output and employment created in the businesses which supply the inputs or materials used by the Institute; and

3. **Induced impact:** output and employment created when workers employed directly or indirectly spend their incomes in the local economy.

Direct impact

JIC employs **378 FTE staff** (full time equivalents) and had an income of **£27.5 million** in 2006/07, having grown year-on-year since 2003/04. Output per head is some £72,800 for JIC staff: a common indicator of productivity. This is considerably below the UK average for natural science research activities (£116,600 in 2006[9]). This can be explained by the fact that a large share of the UK average productivity is comprised of profits made in the private sector, while JIC operates as a not-for-profit organisation.

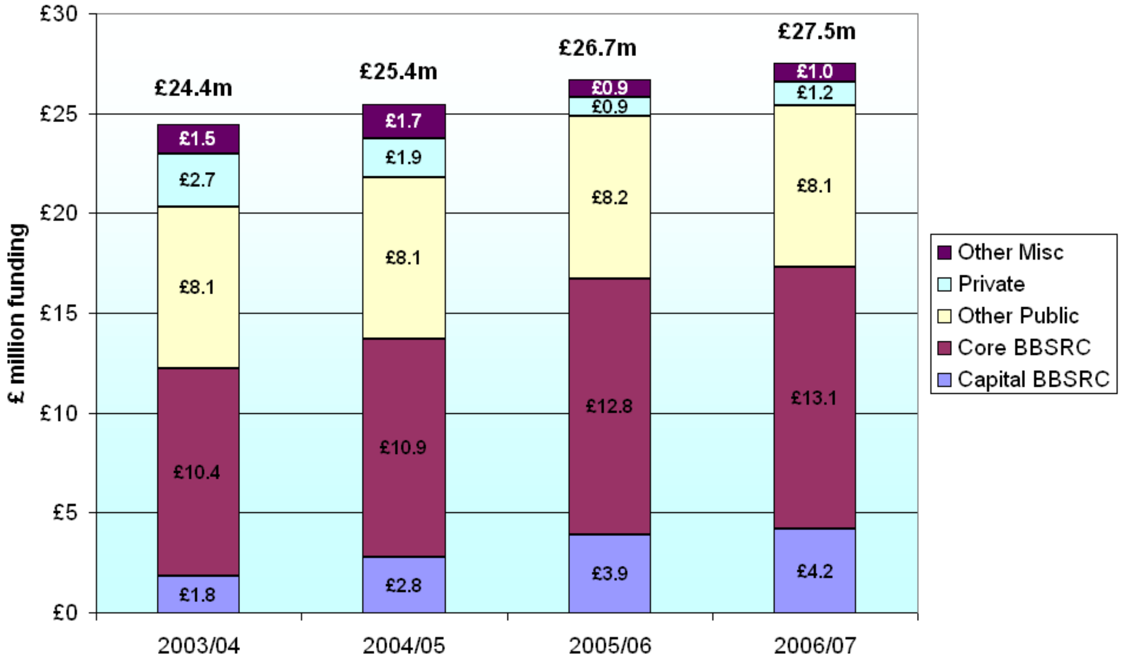
In addition, in 2007, JIC had 110 PhD students, 13 MSc students and a number of visiting workers. These students receive a stipend which varies according to the sponsor. Visiting workers are supported by their host institutions.

Figure 4.1 illustrates JIC's income by source over the last 4 years. Between 2003/04 and 2006/07, total income has grown by some £3.1 million, driven by increases in core and capital BBSRC funding.

The total level and share of private funding has decreased year-on-year. This decline is as a result of major changes in industry. The result is to increase JIC's dependence on public funding to address the market failures identified in section 3.

[9] ONS, 2006 Annual Business Inquiry, Crown Copyright

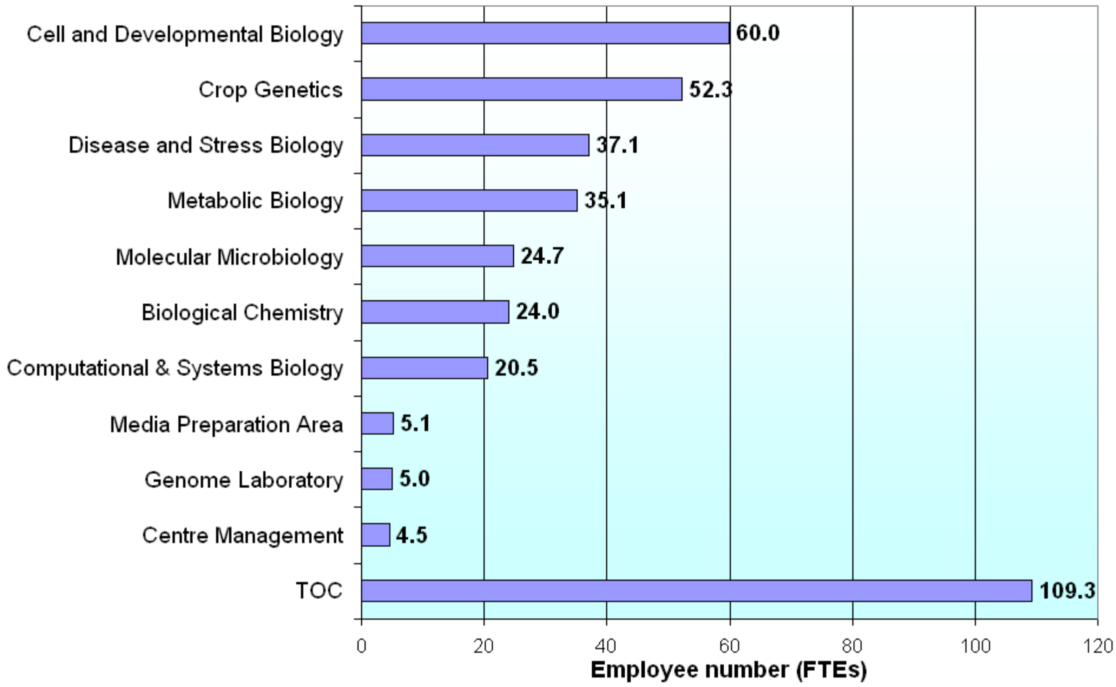
Figure 4.1 – JIC income by source, 2004-07



The 378 FTE staff at the Centre comprises 268 Science staff, with a further 109 from TOC central services. The central services departments are shared with IFR, with JIC allocated a 7/11 share of the 171 TOC staff total. Reflecting a constant level of turnover created by new research emphasis, scientist numbers declined in 2006 by 30, but grew again by 11 over the last year. The central administration services (TOC – The Operations Centre) staff has also declined over the period, now that this represents a shared function with IFR.

Cell & Development Biology and Crop Genetics are the largest single research areas in terms of scientist numbers, each with more than 50 staff. In total, 7 separate research areas have more than 10 employees each, forming the majority of JIC activity. This pattern is summarised in figure 4.2, including those TOC staff allocated to JIC:

Figure 4.2 – FTE Employee numbers by research area, 2007



Source: Human Resources, Norwich Biosciences Institutes

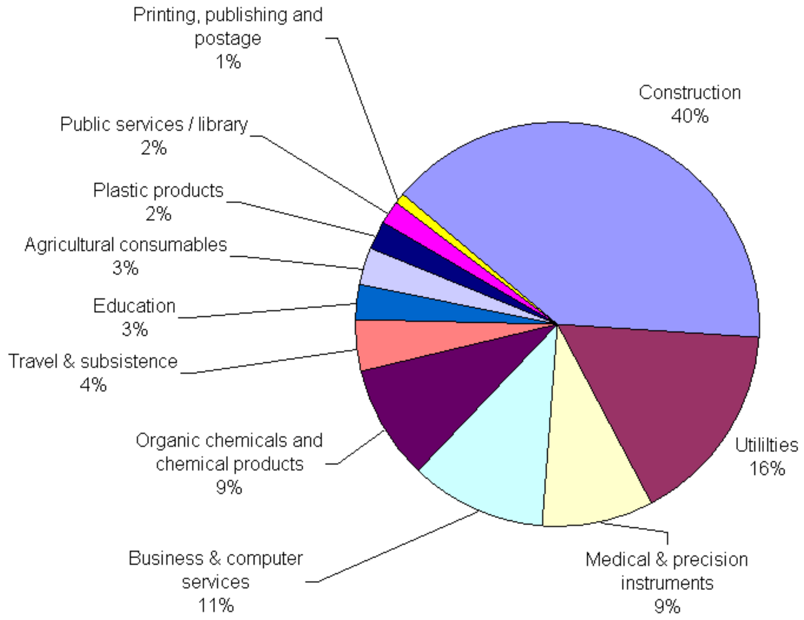
Indirect impact

JIC spent £17 million in 2007 with UK-based suppliers. This supplier expenditure forms the input for calculating the indirect operating impact of the JIC. Figure 4.3 summarises the key areas of supplier expenditure by value.

In 2007, construction was the most significant component of expenditure, financing major and minor site-works. There was also significant investment in capital equipment (classified here together with medical and precision instruments). These investments boosted total supplier expenditure by over £1 million from 2006. Consumables including chemicals, chemical products and plastic products are also a significant component of expenditure.

This profile of supplier expenditure supports output and employment amongst supplier industries, and their suppliers in turn. The extent of this impact can be estimated using the UK National Accounts published by the ONS, estimating the level of expenditure required to support an FTE job in each supplier, and their knock-on expenditure.

Figure 4.3 – Components of JIC expenditure, 2007



In total for 2007, JIC's supplier expenditure is estimated to **indirectly generate a total of £32.1 million output for UK industries, supporting 289 FTE jobs**. This comprises 161 FTEs in those UK companies directly supplying JIC, and a further 128 employed through further supply chain effects (i.e. as JIC's suppliers purchase inputs in-turn from their suppliers, which is still attributable to JIC's initial demand).

Induced impact

Total salaries paid to directly employed JIC staff amounted to £14.3 million for 2007, while salaries paid to those employed indirectly are estimated at £3.9 million. In total, this £18.2 million of direct and indirect salaries accrues to households and will then be spent on a profile of consumer goods and services, generating further economic activity in the UK. This is the basis for calculating induced impact from the Centre.

In addition, the students working with JIC will earn and spend additional income in the area, which is not included within the above staff salaries. In 2007 there were 110 PhD students at the Centre and a further 13 MSc students. Assuming an income of £21,000 per annum for each student (comprising a £12,000 stipend and £9,000 University contribution), this gives total additional income of £2.6 million per annum. This will also contribute to local induced impacts.

Modelling this household income using an average consumer profile across the UK, the **total induced impact of JIC operation amounts to output of £24.3 million, supporting a further 289 FTE positions with associated income of £6.3 million**. While these induced impacts can be attributed to JIC, they will largely occur in sectors out-with the profile of direct and indirect industries, occurring instead in consumer industries such as retail and recreational services.

4.2 Summary of operating impacts

Figure 4.4 summarises the above effects, estimating the total gross impact of the operation of JIC at £83.4m of output, supporting incomes of £30.1m amongst 950 FTEs per annum in the UK. GVA is a measure of productivity which captures the level of salary expenditure and operating profits generated throughout the economy – the operating impact of JIC is estimated to generate £42.4m per annum GVA for the UK economy.

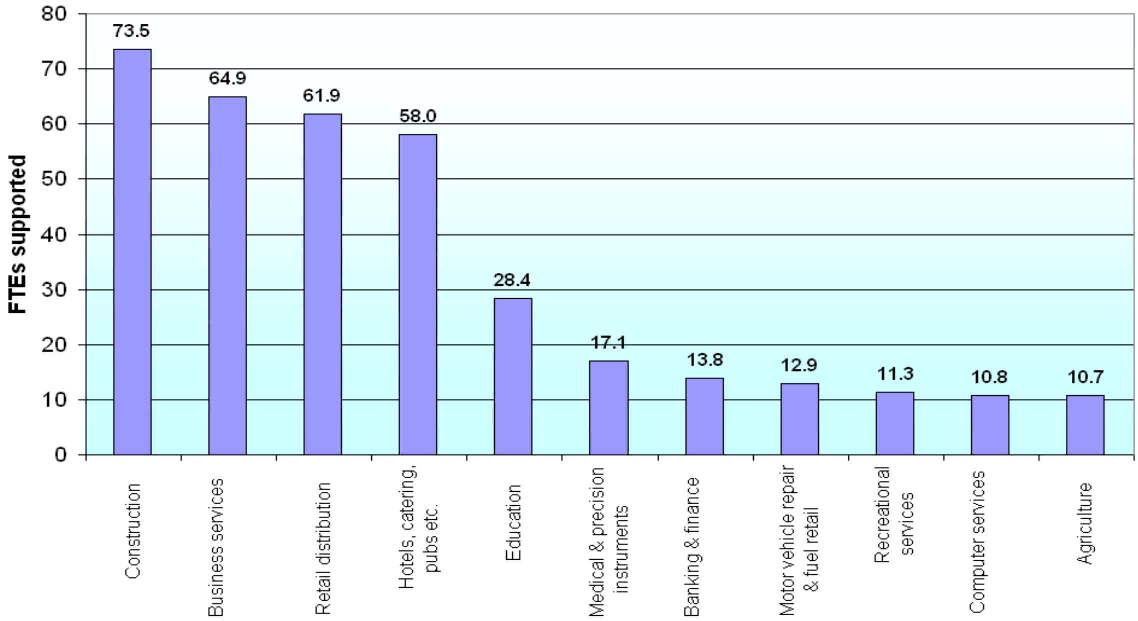
Multipliers illustrate the ratio of knock-on impacts to direct activity: the higher the multiplier, the more beneficial the impact. JIC has a higher than average multipliers across all recorded impacts. This can be caused by a number of factors, but suggests that JIC's are spending proportionately more with suppliers than the UK R&D average, and in higher value sectors.

Figure 4.4
Summary of JIC operating impacts, UK level

Impact type	Output £ Million	Employment FTEs	Income £ Million	GVA £ Million
Direct	£27.5	378	£16.3	£16.3
Indirect	£32.1	289	£7.6	£13.7
Induced	£23.8	283	£6.2	£12.3
Total	**£83.4**	**950**	**£30.1**	**£42.4**
Multipliers				
Implied JIC multiplier	3.03	2.52	1.84	2.60
UK average multiplier	2.32	2.28	1.76	2.21

Figure 4.5 illustrates the profile of those off-site industries that proportionately gain the most from the operation of the JIC. Results are presented for each industry in which more the 10 FTEs are supported through indirect and induced effects. The main beneficiaries are the construction industry and business services (through direct expenditure) and the retail and hotel / leisure sectors (through wage expenditure).

Figure 4.5 – Summary of FTE employment supported in core supply chain industries



5.0 Measuring the impact of JIC research

When measuring the impacts of JIC research, we need to understand the routes to market – the path by which the research is used by product producers or consumers to generate value for them. The range of JIC research is broad, and it is not possible to fully map out the user profile in each case. This report therefore focuses on known and likely impacts of the research. This offers a most robust and tangible approach to impact measurement, but may offer an under-estimation of the full value that research can catalyse.

When attributing a value to these effects, the HM-Treasury's guidance offers the following definitions:

- **Market value**: the price at which a commodity can be bought or sold, determined through the interaction of buyers and sellers in the market.

- **Shadow price**: The opportunity cost to society of participating in some form of activity. It is applied in circumstances where actual prices cannot be charged, or where prices do not reflect the true scarcity value of a good. This approach is used to value non-market impacts (willingness to pay)

Real market prices can measure the strategic value added in the UK economy to production processes, or value to consumers through the use of JIC's research. This can take the form of new sales, avoidance of wastage, or sustaining activities that would otherwise diminish. This is not a "shadow" value, but related to actual impacts and GDP growth experienced at the national level. This will give an estimate of the actual impact of JIC in monetary terms, reflected in national accounting systems, while the further welfare benefits are recognised through qualitative research.

By contrast, the DTI propose a system of shadow pricing when calculating the impact of curiosity-driven research. This involves the estimation of the value of proxy indicators associated with the outputs of research. This method allows research institutes to lay claim to a proportion of existing impacts, though by their nature these "shadows" do not relate to actual activity or economic growth, but a potential value of intangible welfare effects, such as health or environmental improvements.

This impact report attempts to capture both real market and shadow price effects to assess the full economic and social impact of the JIC.

5.1 Final market impacts

The calculation of final impacts for JIC is set out under the following headings:

- Cereal Crops
- Other Crops
- Antibiotics
- Cross Cutting Impacts

5.1.1 Cereal Crops

The work of JIC has had an impact on cereal production through development of higher yielding, stress and disease resistant varieties, with a particular focus on end-use quality.

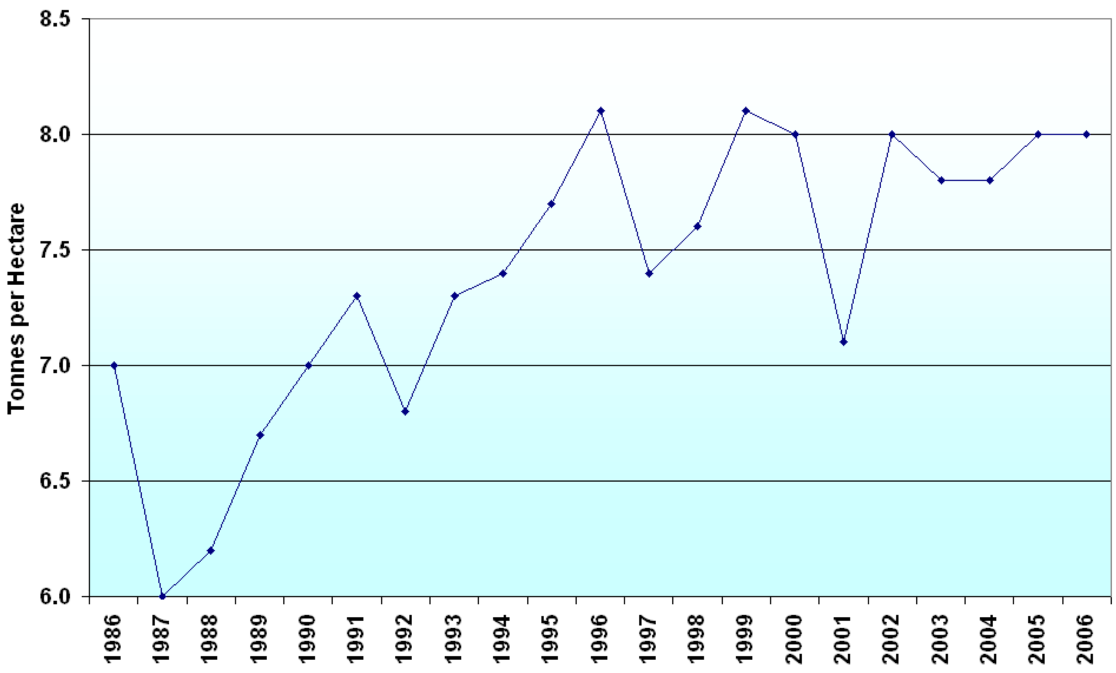
Wheat

In the mid-1970s JIC's work allowed semi-dwarfing genes to be introduced into PBI wheat stocks At that time PBI was involved in public good pre-breeding research. The result was to introduce semi-dwarfing into all UK commercial wheat.

Semi-dwarfing genes shorten the straw. This 'short straw' has a double benefit - more of the growth goes into the ears of wheat rather than the stalk and the standing crop does not lodge. The result is increased yield and reduced wastage from poor harvest conditions.

Figure 5.1 highlights how yields have increased by 14% over the past 20 years, from 7 to 8 tonnes per hectare. JIC estimates that half of this increase in yield is due to semi-dwarfing benefits, with the other half being due to improved agronomy. If we assume that half a tonne of wheat yield increase over the period is due to JIC work, we can calculate a market impact.

Figure 5.1 – 20-year trend in UK Wheat yields, tonnes per hectare



The total value of the UK wheat market was £1.2bn in 2006[10]. Half a tonne represents a one sixteenth increase to reach 8 tonnes per hectare. On that basis, **JIC has helped to increase UK**

[10] Defra

wheat production by £75m per annum. This figure does not take account of the marked increase in wheat prices in the 2007 season so can be considered a conservative estimate.

In terms of the world wheat market, semi-dwarfing gene is present in commercial varieties. If we assume the same level of increase in world wheat we can calculate a global impact.

According to the OECD's World Agricultural Outlook 2007-2016, world wheat production is currently estimated at 596m tonnes, against consumption of 621.4m tonnes. Current world wheat prices are $204 (£102) per tonne for 2006/2007, which will decrease to $183.2 (£91) per tonne by 2016 on current exchange rates. Taking the lower figure, to be conservative, the value of the world wheat market is £54 billion. **If JIC is responsible for a sixteenth of this market value, its contribution to world wheat is £3.4 billion.**

The OECD highlights that world wheat production is expected to reach 672.6m tonnes by 2016, however consumption will be 674m tonnes. This forecast highlights the need for ongoing productivity improvements in wheat production.

Cereal diseases

Over the past 25 years, the major threats to cereal crops have been from leaf blotch, yellow rust and eyespot of wheat, and scald and powdery mildew of barley. These diseases cause total losses of at least £240m per annum in the UK[11] and in addition, the value of the UK cereal fungicide market is at least £100m per annum.

The profile of diseases affecting cereals is changing in response to climatic and agricultural factors. Fusarium spp. poses a major future threat to food safety and export markets while brown rust in wheat and leaf spot in barley are challenging sustainable production.

Fungal diseases are treated using two key strategies:

- Use of **genetically resistant cultivars** - JIC has identified novel sources of resistance to Septoria, Fusarium, eyespot and yellow rust and has worked closely with industry on controlling mildew and Ramularia.

- **Treatment with fungicides** – JIC has researched the evolution of fungi insensitive to certain fungicides thus helping to guide the more effective use of these chemicals by industry.

For example, *Septoria* leaf blotch has always been present in wheat, but never a major problem until the introduction of high yielding susceptible varieties. In 1998 in the UK alone, economic losses from this disease amounted to a cost of £35.5 million[12]. In major wheat production areas of the world, outbreaks are capable of reducing yields by 30–40%[13].

[11] Brown, Prof K M (2007) Personal Communication
[12] Hardwick, N.V. , Jones, D.R. and Slough, J.E. (2001) Factors affecting diseases in winter wheat in England and Wales, 1989–98. Plant Pathol. 50, 453–462.
[13] Eyal, Z. , Scharen, A.L. , Prescott, J.M. and van Ginkel, M. (1987) The Septoria Diseases of Wheat: Concepts and Methods of Disease Management. CIMMYT, Mexico

Using the figures on the wheat market as calculated above, (£54 billion) prevention of *Septoria* leaf blotch alone could help prevent such losses occurring, which based on a figure of 30% losses could amount to previously unrealised wheat production worth some £23 billion in any year. JIC's role in this work might be taken as a fifth given the other institutes and businesses involved. On this basis, **JIC's impact on world wheat production could be as much as £4.6 billion per annum.**

Synteny

JIC's research has established the arrangement of genes in chromosomes and discovered that it is highly conserved between cereal species. This work has allowed JIC to prepare genetic maps of barley, wheat, rice, maize, sorghum and millet.

These maps are effectively 'road maps' to desirable traits. They are now part of the toolkit for research institutes across the world, principally, IRRI in the Philippines which researches rice and CIYMMT in Mexico that researches wheat.

IRRI's annual budget is in the region of $40 million funded by nations from around the world, including the World Bank ($1.7m) as solutions to world starvation are sought through rice production. CIMMYT's annual budget in 2006 was $36 million with $3.5 million coming from the World Bank. JIC's road maps will effectively allow World Bank and other funding to be levered into these organisations and achieve scientific goals more quickly and efficiently. This is a core objective of the World Bank, and on this basis, **JIC can be seen to be leveraging the World Bank funding of $5.2 million (£2.6 million) per annum into these organisations.**

5.1.2 Other Crops

Impact on sales and production

JIC's work on peas focused on improving the efficiency of harvesting. Work in the 1970s focused on the semi-leafless trait and the result is reduced foliage, and improved standing, harvestability and yield. Water use efficiency is also significantly higher.

Variety	Yield (as a % of Radley variety)	Lodging
Semi-leafless	112%	5.4
Normal Leaf	104%	7.3

Data: Canadian Government

100% of the UK dried pea crop (about 80-90% of total production) is now semi-leafless as a result of JIC's work. In addition semi-leafless varieties are used extensively across the world. Figure 5.2 illustrates the value of the UK dried pea market over the past 20 years, valued at £40 million in 1986 and £9 million in 2006 (source: DEFRA):

Figure 5.2 – Value of the UK Dried Pea Market (£ million)

	1986	1990	1994	1998	2002	2006
Peas for harvesting dry	40	43	20	26	20	9

Based on an 8% yield increase, this percentage of the total pea market value would not have been achieved without the adoption of semi-leafless varieties, facilitated largely by JIC. **In the UK, this equated to additional annual sales of £3.5 million** (based on 1990 market value when hectareage was at its maximum). This same ratio can also be applied to the global pea market that has adopted these varieties, as further land would have been required to achieve the same output using normal leaf plants.

JIC has worked jointly with IFR to develop the nutrient quality of broccoli. The so-called ‘super broccoli’ with its high isothiocyanate content is potentially linked to reduced incidence of colon-cancer, modelled under laboratory conditions.

Research by IGD (The International Food and Grocery Information Service), demonstrates through consumer surveys that 36% of shoppers are willing to pay a premium for more nutritious food. It is generally acknowledged that further research is required to estimate the exact rate that consumers are willing to pay for improved nutrition, but surveys offer a fairly consistent picture across other positively viewed attributes. For example, research by the Countryside Agency demonstrates that consumers would be willing to pay a further 5% premium for desirable characteristics such as organic, local produce and sustainable food.

On this basis, with 36% of consumers willing to pay more for nutrition, with an average mark up of 5% generally accepted for beneficial food attributes, this allows a rate of 1.8% of the total value of the broccoli market be attributed to JIC and IFR’s nutrient enhancing research. This offers a “shadow price” approach to measurement, given that markets may not actually be charging the full amount that consumers have stated they are willing to pay. **The impact of JIC’s and IFR’s broccoli nutrient enhancement is therefore estimated at £0.5 million per annum in the UK** alone, based on a market value of £30 million (source: DEFRA).

5.1.3 Antibiotics

There are two key examples of JIC's work in antibiotic development. The first is historic and the second is current.

Historic – JIC discovered the genetic basis of antibiotic production in *Streptomyces*, which are the most important source of antibiotics. It is estimated that *Streptomyces* produce more than 100,000 antimicrobial compounds – 10 times the number discovered so far[14]. JIC provided, and continues to provide, the fundamental science underpinning knowledge-based genetic approaches to the discovery and commercial development of *Streptomyces* antibiotics in diverse large and small companies: in 2005 the market for *Streptomyces* antibiotics was worth over $35 billion.

Current – A brand new spin-out from JIC, Procarta Biosystems, is using JIC science both to improve *Streptomyces* antibiotic productivity, and to counter antibiotic resistance in clinically important pathogens. Another JIC spin-out, Novacta, has grown from six staff in 2002 to nearly 30 now. Novacta is working on solutions for *Clostridium difficile* and MRSA, and has just received over £3M of Wellcome Trust funding to progress their work towards the clinic. Novacta's approach is based on a family of natural antibiotics with potent activity against MRSA and *C. difficile*.

Deaths from *C. difficile* infections in England and Wales rose by 72% between 2005 and 2006 to 6,480, while those attributable to MRSA are estimated to exceed 10,000. The costs of these hospital- and community-acquired infections, and the associated 8.7m recovery days are estimated at £1 billion per annum in England alone. MRSA stabilised at 1,652 in 2006[15]. In addition, research has established the costs of hospital acquired infections in England[16] at £1 billion per annum plus 8.7m recovery days.

The cost of these deaths and lost recovery days can be estimated by assessing the cost of avoiding these outcomes. In 2002 the National Institute of Clinical Excellence (NICE) completed a review of NHS cost-effectiveness estimated the cost *per additional graft saved (lifeyear) or patient death avoided* at £30,000. On this basis, **the value of preventing the 6,480 *C. difficile* deaths could be estimated at £194 million**.

5.1.4 Cross Cutting Impacts

Intelligent Breeding

Traditional plant breeding aims to address problems through crossing of varieties with beneficial traits. Crops have to be closely related for traditional breeding to work and the process takes considerable time. Through 30 man-years of work, JIC has developed 'intelligent breeding' that allows DNA to be taken from any cereal crop to introduce beneficial effects into another.

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[14] Watve MG, Tickoo R, Jog MM, Bhole BD Department of Microbiology, Abasaheb Garware College, Pune 411 004, India. watve@vsnl.com
[15] http://www.statistics.gov.uk/pdfdir/mrsa0208.pdf
[16] Plowman et al (1996), The Socio-Economic Burden of Hospital Acquired Infection, Public Health Laboratory Service.

The benefits of this approach are the ability to fundamentally improve cereal resistance to pest, drought, adverse temperature or other factors in a short space of time. An example is shown in the following table:

Figure 5.3 - Comparison of Traditional and Intelligent Breeding

Traditional breeding	Intelligent breeding
Drought resistance would be gradually introduced by cross-breeding wheat varieties showing drought tolerance over a period of 10-15 years.	Drought resistance of a sub-saharan grass species could theoretically be introduced into East Anglian wheat over one or two seasons.

Known Commercial activity – Industrial income to JIC

We have used the Green Book method of "willingness to pay" to make some indicative estimates of the market impact of JIC activities, represented by increased incomes to private organisations. This recognises that JIC outputs are not all commodities for market sale, but intellectual property that forms the first step in a chain of intermediate suppliers before the final consumer purchase of food produce.

The "willingness to pay" method reflects that private companies will only purchase JIC outputs if they feel that they are able to add value and thus make a profit themselves.

Thus, JIC incomes from private sector companies can be used to recognise the value added by each knock-on process before final market sale of food-based products. Inflation factors have been applied to each stage in the processing chain based on published UK national accounts for profitability in each sector in the chain, to give a prudent estimate of the total value added to the economy through exploitation of JIC near-market research.

At present, JIC have independent collaborations with the UK private sector, and a number through the LINK and EU programmes as follows:

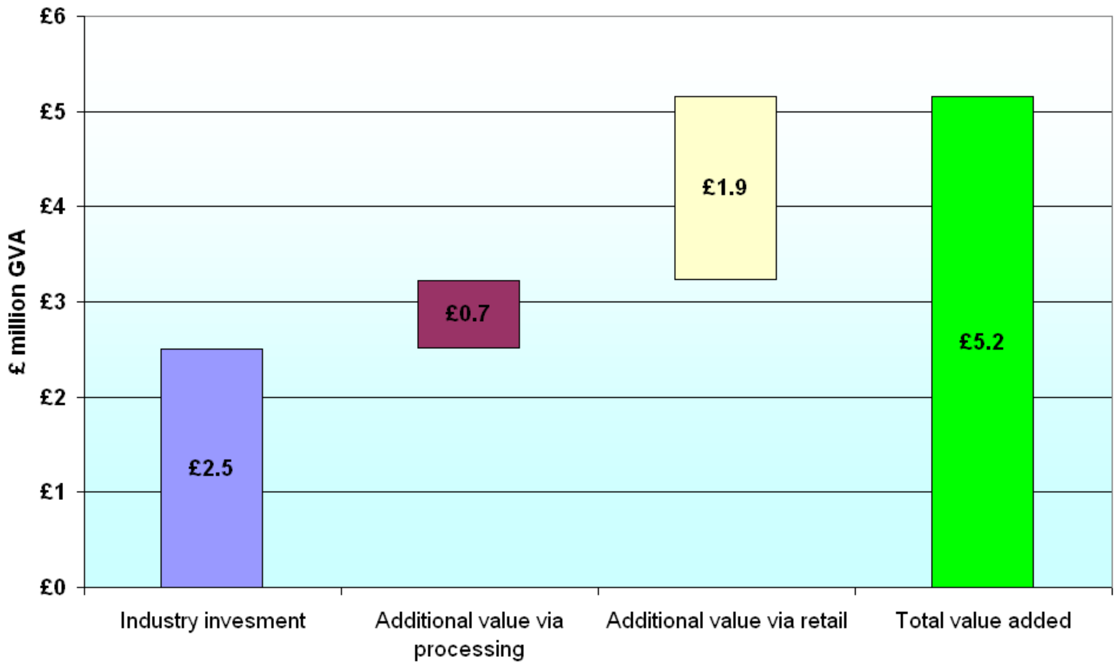
Figure 5.4
Private sector activities, 2006/07

Private income source	Number of partners / collaborations	Value to JIC
Industrial collaboration – LINK	44	£0.3m
Industrial collaboration – other	22	£0.3m
Industrial collaboration – EU	27	£1.9m
Total	**91**	**£2.5m**

Whilst there are a variety of types of company involved, we use the food and drink sector as a proxy for JIC impact. Taking sales of processed food and drink as an example: UK processors add a mark-up of 29% on top of their input costs before sale. At retail, a further 60% mark up is added on average to final products. These mark-ups represent the Gross Value Added (GVA) facilitated by JIC investment, capturing the new wages and profits generated in the private sector.

Figure 5.5 summarises the additional GVA captured through the known exploitation of JIC's research, using weighted average mark-up rates across the sectors providing JIC income. In total, the £2.5 million income from commercial sources to JIC is estimated to generate an **additional £5.2 million GVA** in the economy, that will be recognised in national accounts.

Figure 5.5 – Estimated annual value added through UK commercial exploitation of research



JIC also has industrial collaborations with EU companies and developing countries that amounts to around £1m in annual income.

Together with this income, we can recognise the commercial exploitation of JIC research through the known spin-out companies. The value of their turnover represents a direct market price associated with the value of successful past research. Again, this is measured in terms of a permanent annual output increase. Total impact across the 4 audited spin-outs was some £2.8 million in 2006/07. Combining this with the impact through industrial collaboration gives an **estimated impact of £8 million** through known private sector exploitation of fundamental research.

Known Commercial activity – Licensing patents and start-ups

JIC records information on licensing, patents and start-ups. Figure 5.6 shows that out of 18 patents and breeders rights, five were new in 2006/07. Licenses shows a similar picture. Whilst royalty income is low, JIC shows real potential in increasing commercial application of its research.

Figure 5.6 - JIC licensing, patents and start-ups, 2006/07

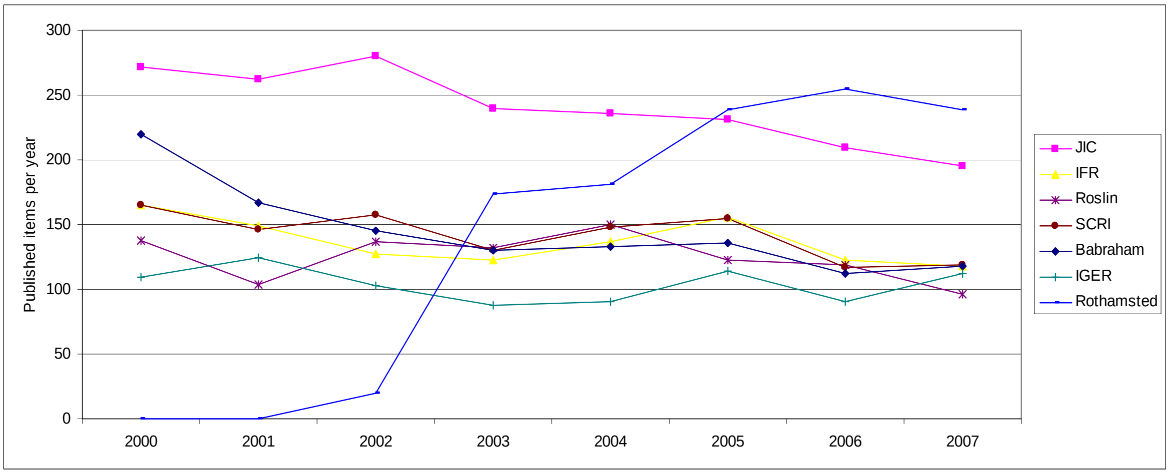
	Total	New
Patents and plant breeders rights held by institute or collaborators	18	5
Licences/options arising from above	13	5
No. of start ups	4	0
Royalty income	£171,000	

6.0 Wider social and qualitative impacts

Peer-reviewed Publications

In terms of total publications, it can be seen that JIC performs well above most peer UK institutes producing 1,950 publications over the period 2000-2007. These data, however, do not take into account the numbers of principal investigators, or staff churn due to changing priorities.

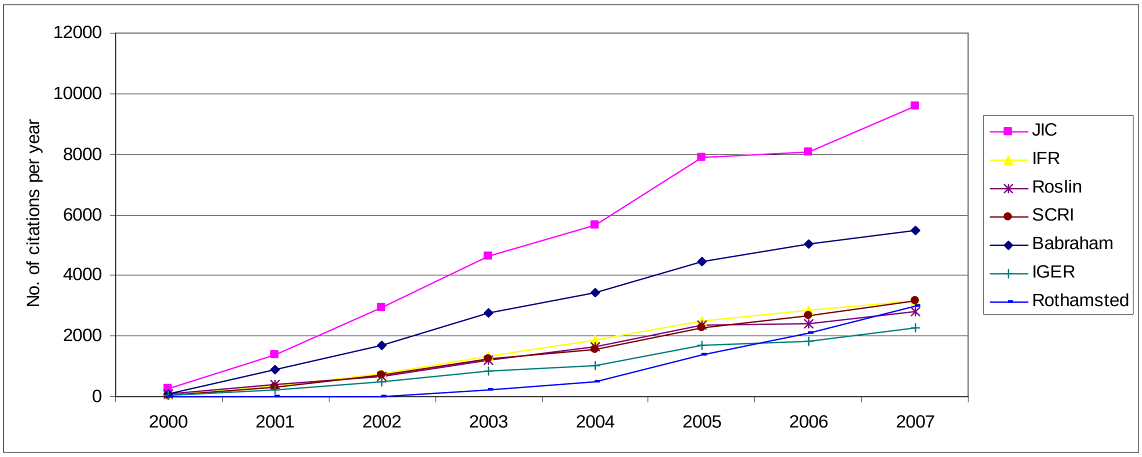
Figure 6.1 Total number of publications produced by JIC and other institutes per annum



Source: Web of Science March 2008
Note: Rothamsted figures exclude publications from the Institute of Arable Crop Research

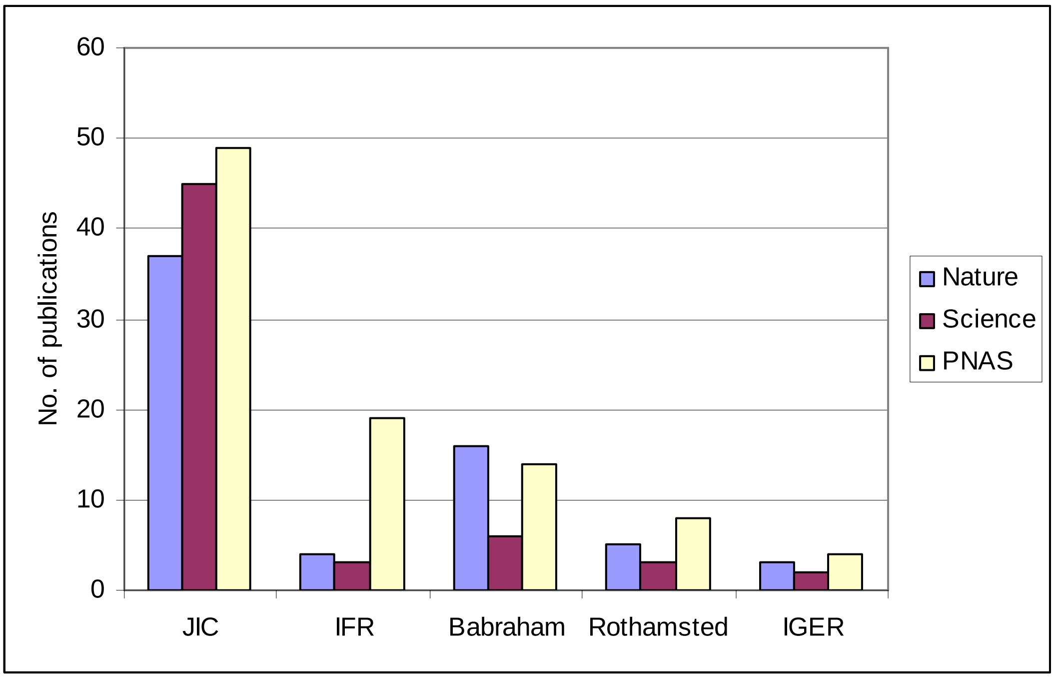
In terms of citations, it can be seen how the body of knowledge that JIC has produced has grown and been utilised; JIC performing well above other institutes with over 42,000 citations across the period. JIC performs ahead of other institutes reflecting its focus on excellent, ground-breaking, fundamental research. Babraham is the only other institute to perform above average, reflecting a similar fundamental focus.

Figure 6.2 Number of citations produced by JIC and other institutes, 2000-07 total



When the quality of publication is considered, JIC performs well above its UK peers as measured by publications in the leading journals of Nature, Science and Proceedings of the National Academy of Science.

Figure 6.3 Quality of publications produced – measured by publications in leading journals 2000 - 2007



Source: Web of Science March 2008

Human Capital

In addition to its permanent staff, JIC has many visiting scientists and students who come for a short time to share knowledge and learn before moving on elsewhere. Numbers of people in these categories are well over 100 at any point in time.

In addition, scientists at JIC move on to other roles, for example, two Max Planck Institute directors and one Oxbridge Professor are former JIC staff.

Furthermore, JIC has influenced the quality of science internationally. For example, former JIC scientists in China form the core of China's biotechnology strategy.

Growing the Economy

JIC has long pointed to the Campus effect of clustering scientific and related organisations together. The presence of JIC, IFR, The Sainsbury Laboratory and the University of East Anglia all create critical mass in science. The JIC BioIncubator takes this further by providing grow-on space for spin-out companies or those wishing to locate close to a large science base. Employees within the JIC BioIncubator have reached 118 staff and continue to grow.

Consideration is being given to a joint Innovation Centre with IFR to attract new companies and enable graduands from the BioIncubator to develop further.

Outreach and engagement with stakeholders

JIC has a longstanding and active programme of activities in this area. It positively encourages and rewards staff to participate and senior scientists have provided high-level service to national and international bodies, enquiries, and parliamentary discussions. One mechanism by which JIC communicates with its stakeholder base is via “Friends of JIC” where activities range from Parliamentary briefings on controversial topics through to local events around JIC science.